

EOS OPERATIONS SYSTEMS: EDOS IMPLEMENTED CHANGES TO REDUCE OPERATIONS COSTS

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ABSTRACT

The authors describe in this paper the progress achieved to-date with the reengineering of the Earth Observing System (EOS) Data and Operations System (EDOS), the experience gained in the process and the ensuing reduction of ground systems operations costs. The reengineering effort included a major methodology change, applying to an existing schedule driven system, a data-driven system approach.

1. INTRODUCTION

The EDOS system currently supports the following five missions: Terra, Aqua, Aura, ICESat and EO-1. Support for the future OCO mission is planned for a start in December 2008. EDOS is a distributed system. Its functions are to capture the X-Band science downlinks data at four ground stations, to transfer the data to a central location referred to as the Level Zero Processing Facility (LZPF), to generate, archive and distribute level zero products to end-users' organizations around the world.

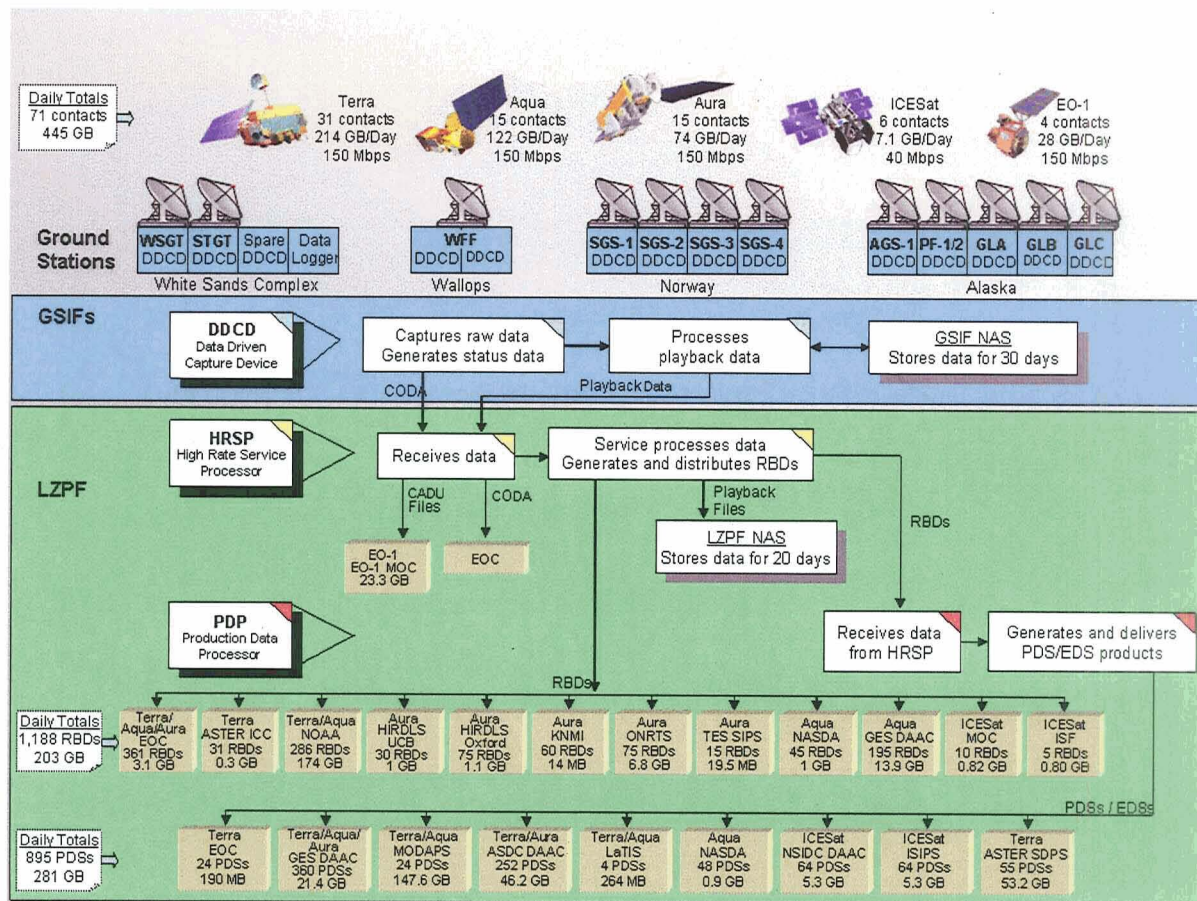


Figure 1. EDOS Ground System Functions, Data Flow and Data Volume

Evolving the system to reduce budgets, increase efficiency and service new missions has been a challenging task. In June 2005, at the 6th RCGSO symposium in Darmstadt, the authors described several initiatives to reduce the workload on operations personnel. It was projected then that a data-driven system would bring about savings in the operations of the system and at the same time increase system reliability.

The data-driven initiative was then pursued actively and the solution was deployed in June 2006 under Phase 1. The current system no longer relies on schedule to capture data and the data processing has been completely automated end-to-end. Under Phase 2 currently under development and targeted for deployment by the end of the fall 2007, all the hosts/servers will be replaced as well as the special hardware providing for added flexibility, performance and several new functions, services. Finally in the proposed plan for Phase- 3 for the 2008-2009 time frame the authors will address system changes associated with products deliveries and products quality assurance automated verification.

2. GROUND SYSTEM OVERVIEW

The diagram in Figure 1 depicts the ground stations and the corresponding antennas with one EDOS Data Driven Capture Device (DDCD) connected to service the incoming data stream. The DDCDs supplied by Kongsberg Spacotec are part of the EDOS Ground Station Interface Facility (GSIF). EDOS receives on average seventy-one contact sessions for a total of 445 Gigabytes of data per day. The incoming data stream triggers the DDCD to capture process and forward the data to the LZPF. The data is also stored into a local archive at the site for 30 days.

At the LZPF, the received playback data from the stations via the IP networks is ingested by the High Rate Service Processors (HRSP) for service processing, generating files ready for distribution to users and/or to the Product Data Processors (PDP). The PDPs then generate the Product Data Sets (PDS) and/or Expedited Data Sets (EDS) for distribution. The playback data files are stored into an archive for some 20 days, should reprocessing of some data be required.

On average, the HRSPs deliver about 1,188 Rate Buffered Data (RBD) files daily for a total of 203 Gigabytes and the PDPs deliver 895 PDSs/ EDSs for a total of 281 Gigabytes. EDOS initiates the transfer of the Rate Buffered Data (RBD) within 5 minutes after LZPF receipt of all data for the contact session. EDOS delivers the PDSes within 24 hours of receipt of all appropriate input data. Similarly the EDSes are delivered within 60 minutes to the users.

EDOS also initiates the transfer of Customer Operations Data Accounting (CODA) status data for data quality and statistics monitoring to the control centers within 1 second of receiving data and continues transfers in 5 seconds intervals.

3. EDOS DATA-DRIVEN - PHASE 1 JUNE 2006

3.1 Design

The data-driven solution was presented last June at the SpaceOps conference in Rome (2006) in a paper titled "Autonomous multi-missions, multi-sites X-band data capture systems", at a time when the solution was actually being deployed on the systems. Kongsberg Spacotec's presentation at the 7th RCGSO symposium will address the engineering design of the DDCD device, the solution and future enhancements.

EDOS custom application software and processes running at the LZPF on Silicon Graphics and IBM AIX servers had to be modified to remove all the schedule dependencies leading to a major system simplification.

3.2 Features and Benefits

To meet the goal of increasing efficiency and reducing operation costs while meeting the original performance requirements, the system had to perform the following:

- Autonomous capture of high rate data for supported missions at each antenna with no schedule input using new Kongsberg-supplied Data-Driven Capture Devices (DDCD)
- Automatic transfer of high rate data to LZPF with no schedule input
- Automatic "reconciliation" of data transferred to LZPF
- Automatic LZPF data product generation and distribution

- Automation of EO-1 data capture and distribution
- Use of new LZPF Network Attached Storage to retain data received for 25 days
- Re-processing requests serviced from the LZPF Network Attached Storage
- Use of Nagios for real-time monitoring of all DDCDs

The expected resulting benefits would then translate into

- Reduction of EDOS operation costs by automating routine data capture and processing
- Reduction of missed passes and reduction of FOT rescheduling efforts
- Streamlining of the EDOS system architecture by reducing software and database complexity
- Positioning the project for Phase 2 EBOX technology upgrade, associated automation and re-engineering efforts
- Automation of the manual EO-1 processing

3.3 System Transition

The system transition took place on June 14th, 2006 and within 24 hours; all sites were converted to the data-driven solution with minimum impact to the latency on product deliveries for that day. Operations personnel directed the transition with the support of engineering personnel at the ground sites. The strategy involved migrating progressively the functions to the data-driven system as Operations personnel continued the processing of the mission data on the backup system through the day.

3.4 Problems experienced and Resolution

Prior to deployment, the data-driven solution was evaluated through systems tests and acceptance testing phases on a separate test system string end-to-end. Most known bugs were resolved by the KSPT and EDOS developers and the system was accepted for deployment into operations.

Several intermittent problems were experienced shortly after transition.

Captured files on the DDCD had incorrect AOS and LOS times, creating a situation where the data would not be included in products creation at the LZPF and thus contribute possibly to incomplete products. Data overflows began to appear after several days and it was realized that there was a memory leak associated with the middleware task. Files transfer failed the reconciliation using the checksum. At times, the processing queue would be affected when an item would be in a hung status. Finally, there were other problems with the EDOS backend application software, service processing, product data processing and communication tasks which were fixed as they were uncovered.

All the problems above have since been resolved by the respective developer parties.

3.5 Performance analysis to-date

The replay factor was the parameter of choice to measure the impact of the data-driven solution on EDOS operations.

The replay characterizes the manual process required by operations to re-ingest the data into the DDCD from the ground station Line Outage Recorder (LOR). The analysis of the replays statistics to assess the design improvement or lack of, when operating the system in a data-driven mode, is based on the data collected at the WSC ground station, where EDOS captures the Terra X-band science downlinks at 150 Mbps from TDRS every 45 minutes or so. Alaska, Norway and Wallops ground stations have shown more variability because of natural events including winds, flood and/or power loss, com equipment malfunction,

The data shown in Figure 2 represents the average monthly replays performed by EDOS operations since July 2004. The data is shown for three time periods, the first extending from July '04 through May 2006, the second from June 2006 through December 2006 and the last from January 2007 through April 2007.

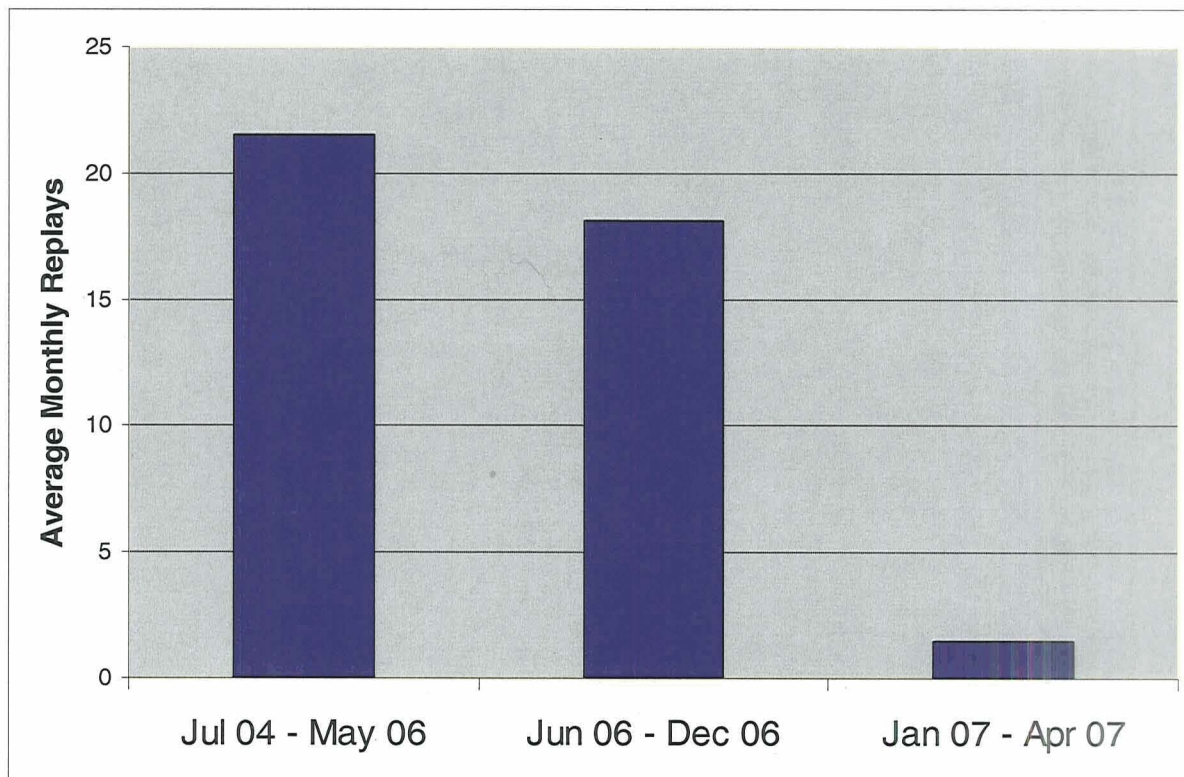


Figure 2. Terra Monthly Average Replay Statistics

Until June 2006, the system was in a schedule driven mode with an average of 22 replays per month, mostly due to problems with system scheduling of resources. The second period shows an average of 18 for the data-driven system, not a significant improvement due to problems previously mentioned in section 3.4. Then, finally after all the fixes were implemented, the average dropped dramatically to 1.5.

It took about 6 months to reach a new all time high in system dependability. At no time since June 2006, has the data-driven system failed to ingest the incoming data stream and to identify correctly the mission data at all four ground sites. A performance level has now been achieved to enable further cost reduction in operations support.

3.6 Lessons Learned

The data-driven solution has brought about a major system simplification. Since it was deployed, there have been at least 26,000 spacecraft contact sessions and all missions contacts were correctly identified by the data capture-ingest task. This is the solution of choice given the constraints imposed on EDOS in servicing the missions.

A few unexpected glitches on the software code created initially modifications to the operators' procedures where operations personnel had to pay careful attention to make sure the problems did not contribute to data losses. A lesson learned here is to never expect the software to be error free. The software patches deployed afterwards have made this system highly dependable as suggested by the replay number statistics since January 2007 for WSC, out of 3,600 passes, there were less than 5 replays.

There are risks associated with major system reengineering changes such as converting a schedule driven system to a data-driven system. Best mitigation approach still is a separate test system with ample testing time to uncover the

defects. Where possible, the best approach suggests also a period of parallel operations before the system is placed on line. The EDOS systems have now reached a new high level of dependability, flexibility and autonomy.

4. EDOS DATA-DRIVEN - PHASE 2 November 2007

EDOS' evolution continues based on the successful Phase 1 experience to enhance further the data-driven solution and to bring into reality the concept of the EDOS-in-a-Box (EBox) where, with a single piece of hardware, EDOS can capture, process, and deliver science data products. Refer to Fig 3.

- The EBox supplied by KSPT (HP ML570) configured in the "send" mode (EBox-S) deployed at the GSIFs replaces the DDCD and can be configured to perform data driven capture, CADU transfer, service processing, production data processing and delivery.
- The EBox configured in the "receive" mode (EBox-R) deployed at the LZPF replaces both the HRSP and PDP processors.
- The Monitor and Control System (M&CS) will provide via enhanced GUIs a centralized and streamlined view of health & status of EDOS components, processing, enhanced anomaly reporting, and elimination of tracking forms

The EDOS phase 2 architecture extends the performance capabilities of the existing C5.0 system and eliminates all operator interaction during nominal support and integrates better with Flight operations support.

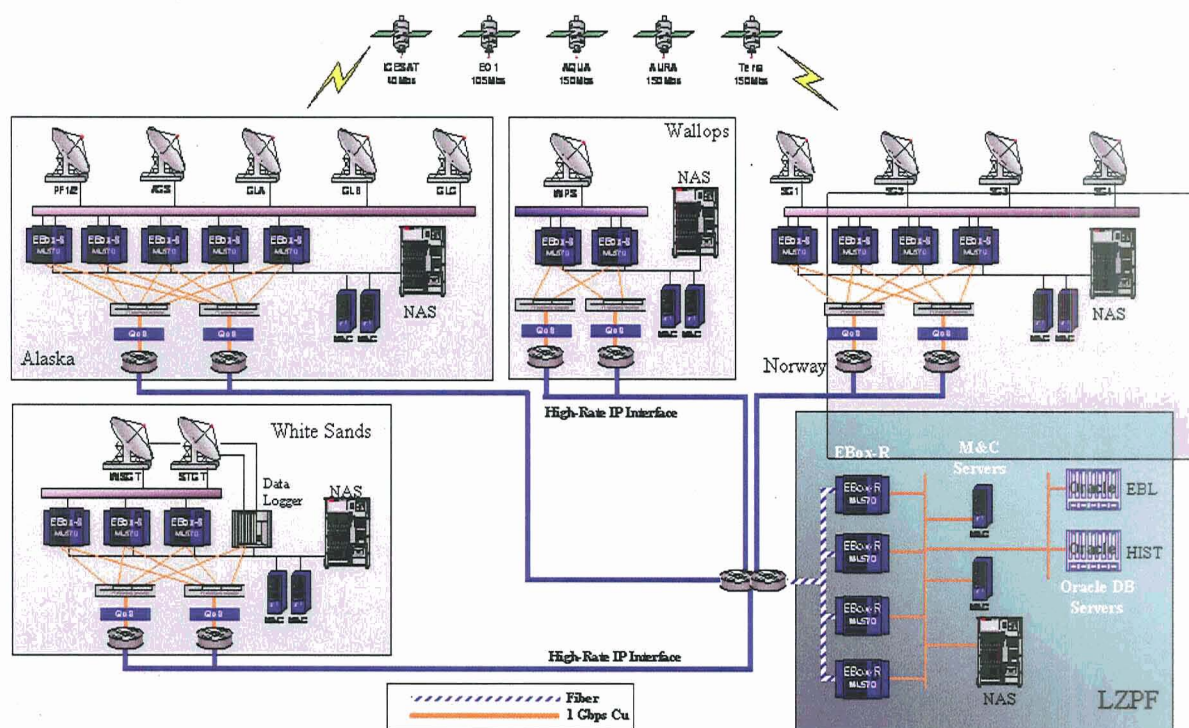


Figure 3. EDOS Phase 2 Architectural Overview

4.1 Phase 2 Key Design Guidelines

The following key design points are guiding the current effort:

- Standardization of all EDOS operator screens to a unified set based on JAVA and accessible through a web browser. An additional external web server will allow the ground stations, FOT, and science teams to non-intrusively observe the EDOS capture and production status at any time and take necessary corrective actions if needed
- Operation of the system requiring intervention only on system anomalies and not during nominal cases via a central control and monitoring system
- Incorporation of new FEP design that increases EDOS spacecraft downlink capture rate up to 500 Mbps and allows in-system reconfiguration/ upgrades via FPGA image files
- Allowing to create level zero products right at the ground station and option to deliver data in real-time; "EDOS-in-a-Box" capability to support Remote Science Processing for disaster recovery
- Consolidation of the High Rate Service processors and the Production Data Processors into single units, reducing the amount of hardware, replacement of obsolete SGI technology and use of a single operating system (LINUX) to simplify system administration. Reduce the number of science processing machines in the LZPF from 7 per configuration to 3
- Implementation of a GMSEC bridge to provide status data feed to external automation engines.
- Upgrades hardware at ground stations to the latest technology reducing hardware obsolescence risks.
- Automated Session and Product Status reporting.
- Capability to prioritize traffic between the GSIFs and the LZPF high rate lines via QoS implementation
- Archive data storage based on disks and no longer on tapes

4.2 Phase 2 Development Status

The integration of the components into a test system is currently ongoing at GSFC. A test string has been configured to incorporate the hardware platforms, the application software and other software components as they become available from the respective developers.

The KSPT team efforts are focused in delivering the EBox-S, the EBox-R and the M&CS systems including the MEOS software and the middleware components. To mitigate a delay incurred with the production of the new ingest IO 2100 boards, a pair of prototype boards will be shipped earlier and inserted in the test system to enable the evaluation of the data ingest process at the earliest opportunity.

The EDOS developers concentrate their effort on the configuration and integration of the EBox-R which performs the service processing, the production data processing and the product distribution. The legacy software has been ported to run on a new platform and o/s environment under Linux Suse 10.1; the porting of the software from Silicon Graphics servers to newer HP platforms was a major conversion task.

Additionally both teams are finalizing the GUI screens and functionality to support streamlined operations. It is anticipated that the integration testing and acceptance testing would not complete before October 2007. Pending on the confidence level obtained during the testing and the amount of parallel operations required, the system would not be deployed before mid-November 2007 at the earliest.

4.3 Post Phase 2 Items

The EDOS system will be modified to support changes evolving from Auto-Ops mode of operation of the spacecrafts. Because EDOS performs the service processing per individual contact sessions, a technique to recover the CCSDS packet contained in multiple frames across contact sessions will be developed.

For the OCO mission, there is a need to develop a capability to extract in real-time several virtual channel data from the X-band downlink as the data is ingested on the ground and to forward the data with the least amount of

delay to an end-destination. The capability to stream data across the networks for several virtual channels is also new and will be provided shortly after the C5.1 delivery.

5. EDOS DATA-DRIVEN - PHASE 3 November 2008

Under the current operational configuration and with the C5.1 configuration as well, EDOS delivers products autonomously by using a “push” method depositing the data into directories on the end-users’ servers. A preferred way to distribute the products would be for EDOS to push all products to a central server and let the users pull their respective data from the server. The data would remain available on the server for 10 days. This would reduce the workload on the EBox-R servers which receive the data, process it and generate the data products.

At times, due to problems at the ground station, communications lines problems, the data may not be transferred back to the LZPF in the correct time order. That situation then may trigger prematurely builds of products and, as a result, generate incomplete products. With the GSFC Mission Services Evolution Center (GMSEC) automated tools, EDOS plans to develop automated “quality assurance” processes to detect and report on these anomalies.

6. SUMMARY

The data-driven solution deployed under Phase 1 simplifies operations in a major way and the methodology has been validated. Credits go to the KSPT and the EDOS development teams to resolve the bugs on a timely basis.

Under Phase-2, all computer/ hosts processors will be replaced with a single type of platforms, one o/s and operations personnel focus on anomalies reporting only. This will be a major system transition as almost every single piece of hardware in the system will be replaced.

Under Phase 3, the delivery of the products by EDOS to a central server will be more in line with an optimized approach for products distribution as end-users systems would pull the products from the central server.

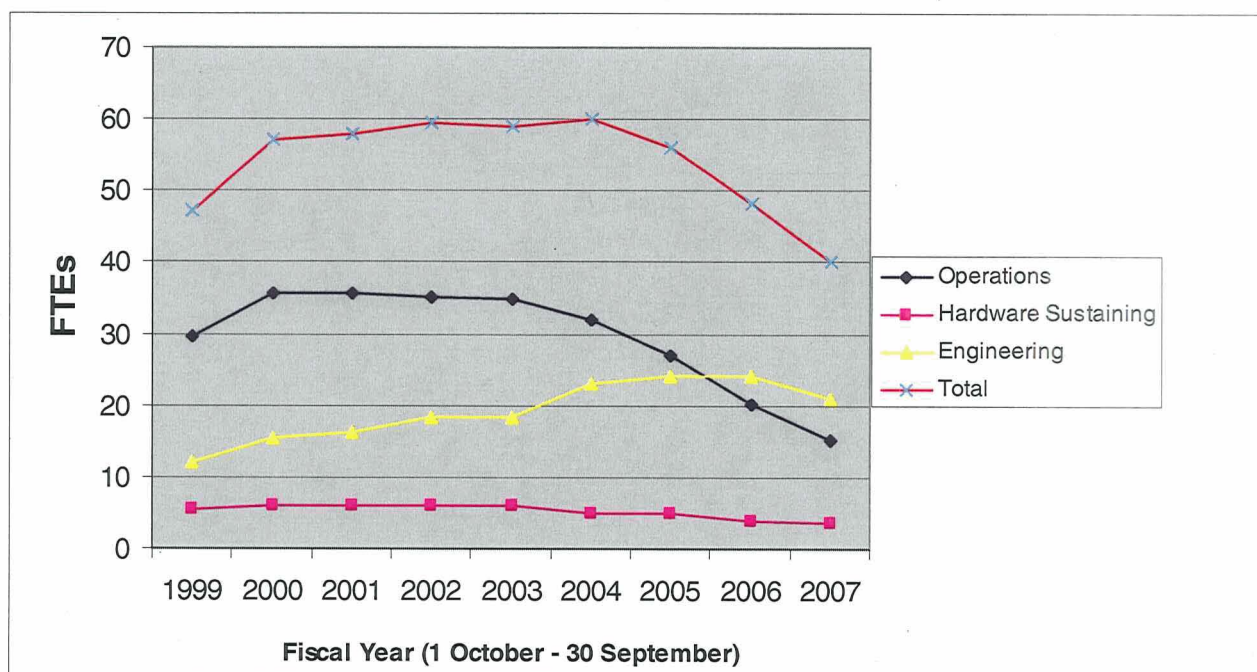


Figure 4. EDOS Staffing Trend

Figure 4 depicts the downward trend with the staffing of personnel supporting the workload of 5 missions and in the planning of adding the OCO mission and support for ALOS. As more missions make use of the existing antennas supported by EDOS at the ground stations and the high rate networks in place to deliver the data, significant savings continued to be achieved on the individual programs.

Figure 5 depicts the EDOS total cost profile referenced to Fiscal Year 2002

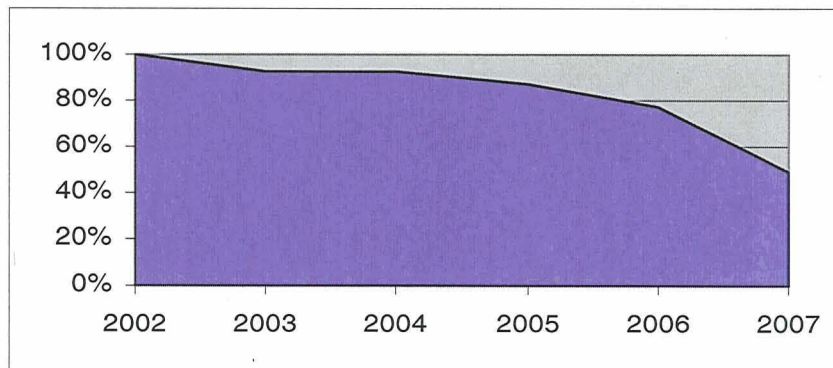


Figure 5. EDOS Total Cost per Fiscal Year

The following comments interpret the curve trends in Figure 5

- In 2003, the drop reflects a decline in system development costs.
- In 2004, operational efficiencies are realized leading to a reduction of operations, management and administrative positions.
- In 2005, the reduction in mission engineering and project troubleshooting positions continued as on-orbit missions stabilized into routine operations and there was limited new mission development work.
- In 2006, the NAS implementation eliminated maintenance costs of Ampex tape drives and tape handler positions. Further operational efficiencies are achieved as the system stabilized and became more automated

The consolidation of functions into a reduced number of computers and the use of a single operating system contribute to the reduction of maintenance costs. The added high system reliability reduces as well the need for technical assistance at the remote sites. As an example, the data-logger at WSC has been operating in a LOR mode with no site personnel support needed since October 2005.

6. Acknowledgments

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EOS Operations Systems



EDOS IMPLEMENTED CHANGES TO REDUCE OPERATIONS COSTS

7th International Symposium

Reducing the Costs of Spacecraft Ground Systems and Operations (RCSGSO)

Moscow, Russia

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Guy R. Cordier / Lockheed Martin Mission Systems
Carlos Gomez-Rosa / NASA Goddard Space Flight Center
Bruce D. McLemore / Honeywell Technology Solutions, Inc.



Topics



- Introduction
- EDOS Ground System Overview
- Data-Driven Implementation – Phase 1 (Completed June 2006)
- Data-Driven Architecture – Phase 2 (November 2007)
- Data-Driven Architecture – Phase 3 (November 2008)
- Summary



Introduction



Under the Earth Sciences Mission Operations (ESMO) Project,
The EOS Data and Operations System (EDOS) refers to the distributed multi-
mission High Rate ground system currently supporting
Terra, Aqua, Aura, ICESat and EO-1

Orbiting Carbon Observatory (OCO) mission to be added Dec 2008 Potential support for Advanced Land Observing Satellite (ALOS) in 2008

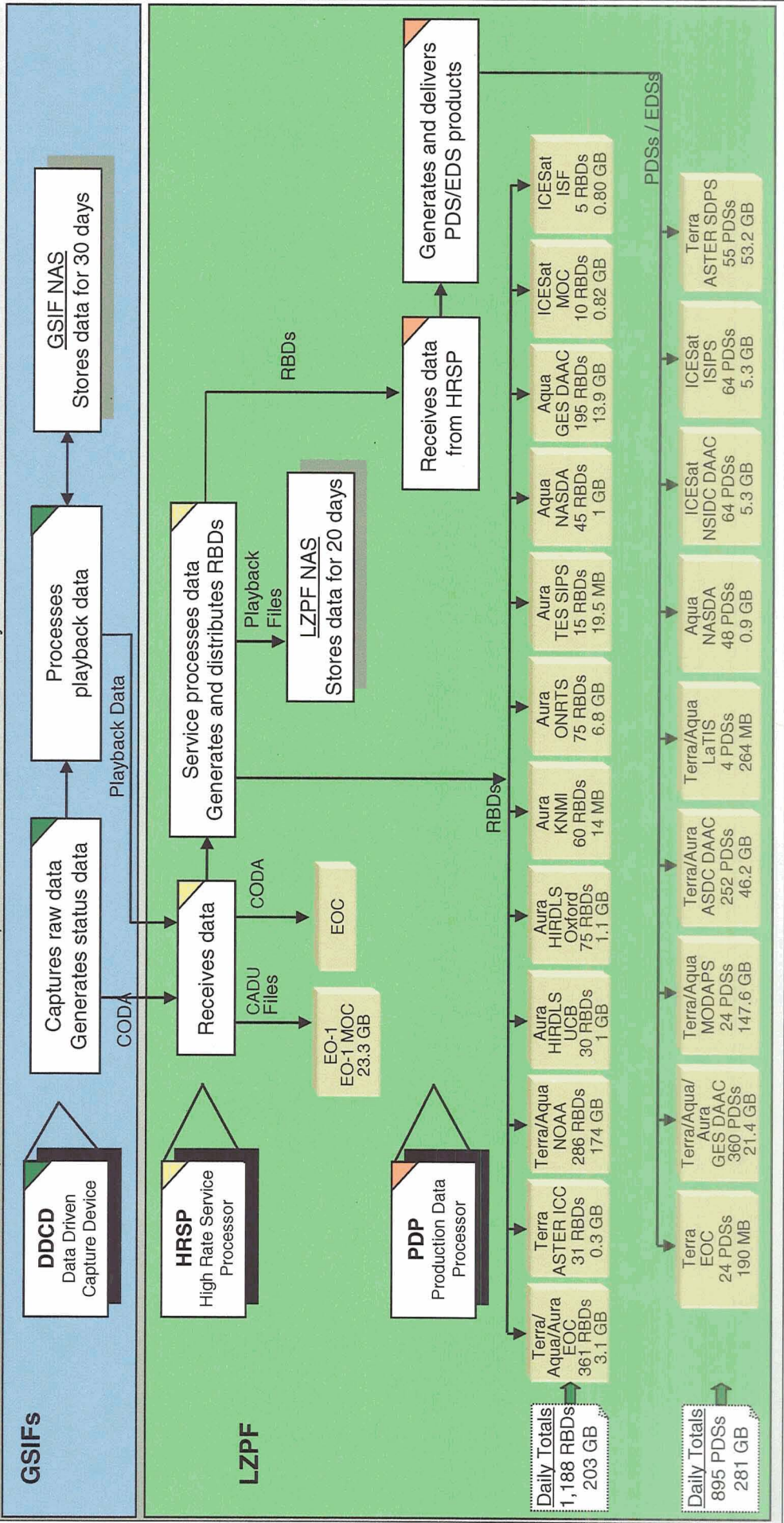
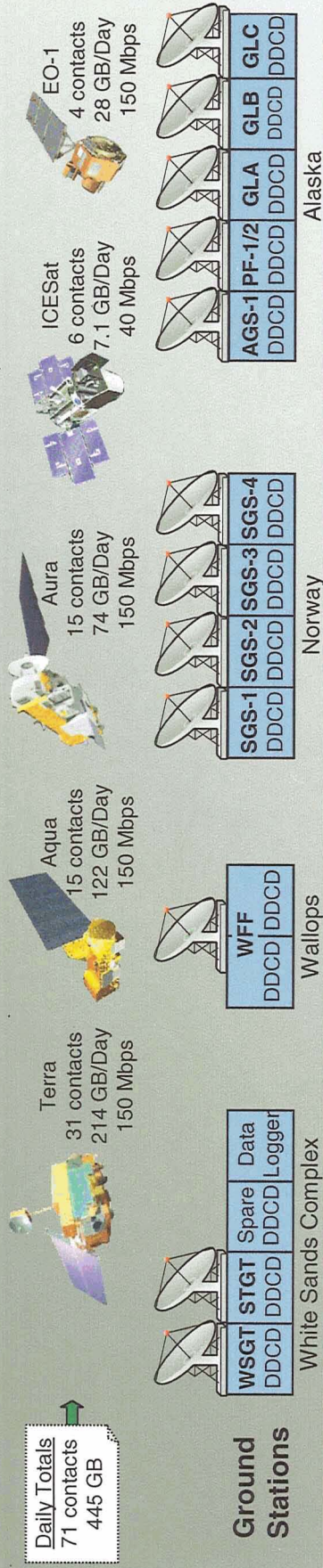
This paper addresses the system evolution as follows:

- The data-driven initiative* deployed last June, 2006 under phase 1, associated results, performance and foundation for cost savings
- The on-going effort under phase 2 to upgrade the special purpose hardware and computers and add new functions in late fall 2007
- A proposed plan for phase 3 in the 2008-2009 time frame to deploy a central data products server and automated quality assurance tools

EDOS Evolution Continues...

* The plan was presented in a previous paper at the 6th RCSGSO symposium in Darmstadt in June 2005

EDOS Ground System Functions





EDOS Ground System Acronyms



AGS – Alaska Ground Station	LaTIS – Langley TRMM Information System
ALOS – Advanced Land Observing Satellite	LZPF – Level Zero Processing Facility
ASDC – Atmospheric Science Data Center	MB – Megabyte
ASTER – Advanced Spaceborne Thermal Emission and Reflection Radiometer	MOC – Mission Operations Center
CADU – Channel Access Data Unit	MODAPS – MODIS Adaptive Processing System
CODA – Customer Operations Data Accounting	MODIS – Moderate Resolution Imaging Spectroradiometer
DAAC – Distributed Active Archive Center	NAS – Network Array Storage
DDCD – Data Driven Capture Device	NASDA – National Space Development Agency of Japan
EBox – EDOS in a Box	DAF – Data Archive Facility
EDOS – EOS Data and Operations System	NOAA – National Oceanic and Atmospheric Administration
EDS – Expedited Data Set	NSIDC – National Snow and Ice Data Center
EO-1 – Earth Observing 1	OCO – Orbiting Carbon Observatory
EOC – EOS Operations Center	OMIS – Ozone Monitoring Instrument System
EOS – Earth Observing System	ONRTS – OMIS Near Real Time System
FOT – Flight Operations Team	PF – Poker Flats
GB – Gigabyte	PDP – Production Data Processor
GES – GSFC Earth Sciences	PDS – Production Data Set
GLA – Gilmore Creek Alpha	RBD – Rate Buffer Data
GLB – Gilmore Creek Beta	SDPS – Science and Data Processing Segment
GLC – Gilmore Creek Charlie	SGS – Svalbard Ground Station
GDS – Ground Data System	SIPS – Science Investigator Processing System
GSFC – Goddard Space Flight Center	STGT – Second TDRSS Ground Terminal
GSIF – Ground Station Interface Facility	TDRSS – Tracking and Data Relay Satellite System
HIRDLS – High Resolution Dynamics Limb Sounder	TES – Tropospheric Emission Spectrometer
HRSP – High Rate Service Processor	TRMM – Tropical Rainfall Measuring Mission
ICC – Instrument Control Center	UCB – University of Colorado Boulder
ICESat – Ice, Cloud and Land Elevation Satellite	VCDU – Virtual Channel Data Unit
ISF – Instrument Support Facility	WFF – Wallops Flight Facility
ISIP – ICESat Science Investigator-led Processing System	WSGT – White Sands Ground Terminal



EDOS Ground System Products Requirements



- **Rate Buffered Data (RBD) sets to users**
 - Within 3 hours of observation (initiate transfers within 5 minutes after data receipt at LZPF)
 - Goal: Within 1 hour from LOS at the GSIF
- **Production Data Set (PDS) to users**
 - Within 24 hours of data receipt at GSFC, 99% of the time
- **Expedited Data Set (EDS) to users**
 - Goal: Within 1 hour after data receipt at LZPF
- **Customer Operations Data Accounting (CODA) reports to users**
 - Within 1 second of data receipt, then continue transfers at 5 second intervals



EDOS Ground System Architecture

Phase 1



Key New Features...

- Autonomous capture of high rate data for supported missions at each antenna with no schedule input using new Kongsberg-supplied Data-Driven Capture Devices (DDCDs)
- Automatic transfer of high rate data to LZPF with no schedule input
- Automatic “reconciliation” of data transferred to LZPF
- Automatic LZPF data product generation and distribution
- Automation of EO-1 data capture and distribution
- Use of new LZPF Network Attached Storage to retain data received for 25 days
- Re-processing requests serviced from the LZPF Network Attached Storage
- Use of Nagios for real-time monitoring of all DDCCDs



Data-Driven Implementation

Phase 1



With the following goals in mind...

- Reduction of EDOS operation costs by automating routine data capture and processing
- Reduction in number of missed passes and FOT rescheduling efforts
- Streamlining the EDOS system architecture by reducing software and database complexity
- Positioning of the project for Phase 2 EBOX and associated automation and re-engineering efforts
- Automation of the manual EO-1 processing performed
- Data-driven makes EDOS more competitive and more attractive to new missions



Data-Driven Implementation

Phase 1



Acceptance Testing...

- Prior to deployment, the data-driven solution was evaluated through systems tests and acceptance testing phases on a separate test system string end-to-end.
- Most known bugs were resolved by the KSPT and EDOS developers and the system was accepted for deployment into operations.



Data-Driven Implementation

Phase 1



System Transition To Operations...

- The system transition took place on June 14th, 2006
- Within 24 hours; all sites were converted to the data-driven solution with minimum impact to the latency on product deliveries for that day
- Operations personnel directed the transition with the support of engineering personnel at the ground sites
- The strategy involved deploying progressively the functions onto the system while Operations personnel continued the processing of the mission data on the backup system through the day.



Data-Driven Implementation

Phase 1



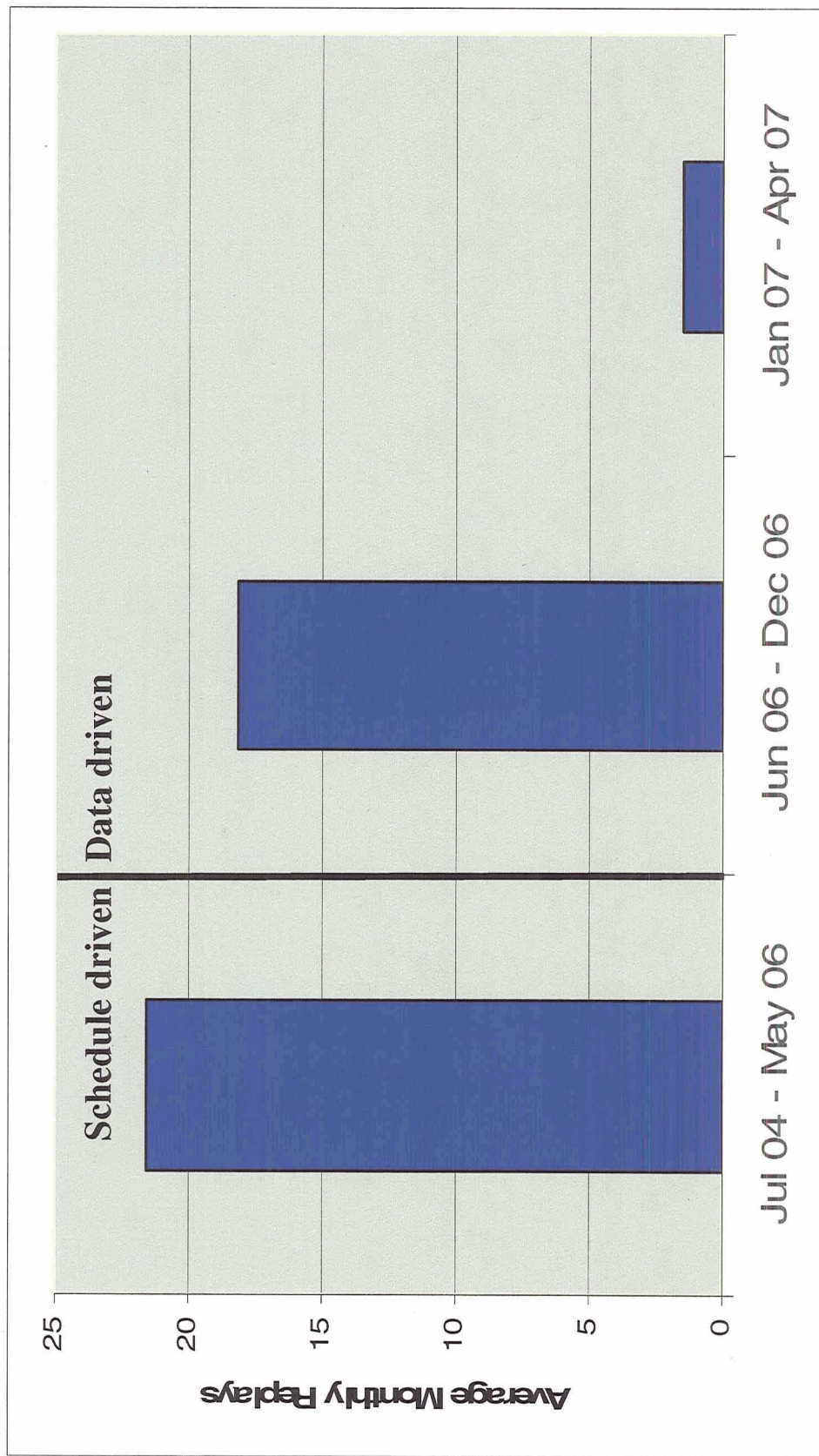
Some intermittent problems were experienced shortly after transition...

- Incorrect AOS/LOS in file times
- Data overflow
- Checksum errors
- Processing queue hangs
- EDOS backend problems

These problems have since been resolved by the respective developers (see next slide)



Data-Driven Implementation Terra Replays





EDOS DATA-DRIVEN PHASE 2

November 2007



So why upgrade again?

- Current and long-term initiatives will focus on reducing operations costs to current users and on creating an EDOS that is extendable for new mission support.
- This includes initiatives that automate EDOS functions, eliminate all operator interaction during nominal support, integrate better with Flight Ops and other ESMO functions, provide portability, and streamline/simplify the EDOS network architecture.
- Drivers:
 - Cost reduction
 - New mission capability



EDOS DATA-DRIVEN PHASE 2

November 2007

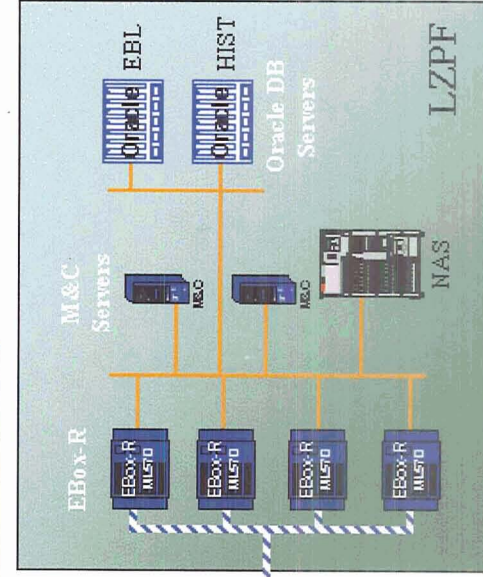
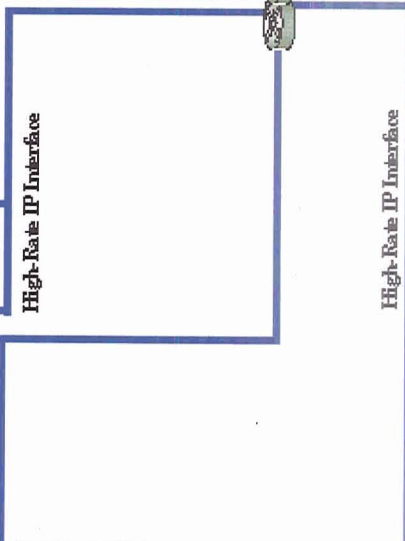
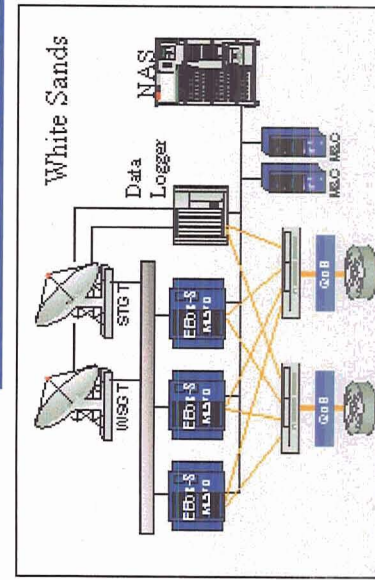
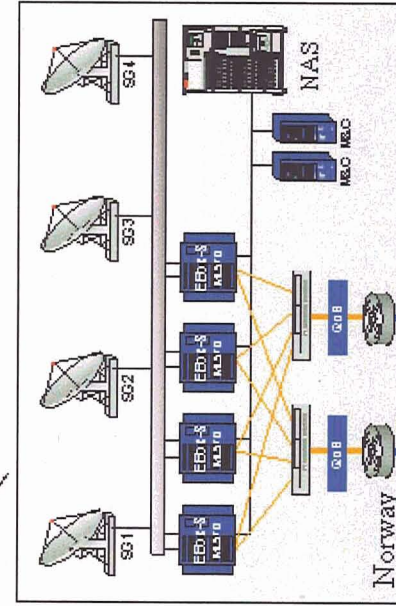
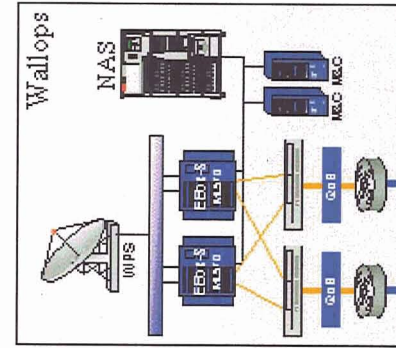
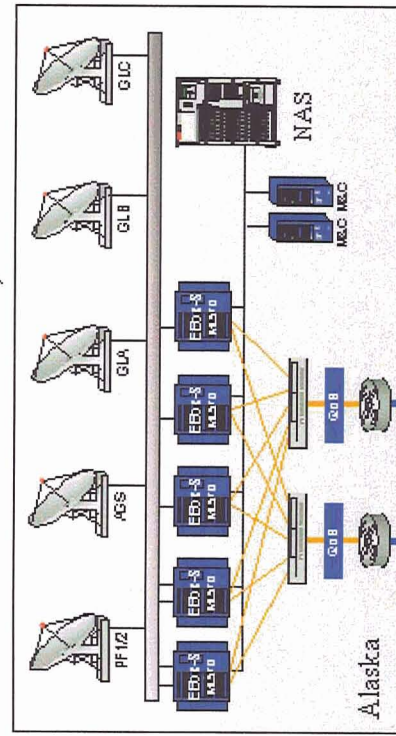


Based on the successful Phase 1 experience, EDOS continues to enhance the data-driven solution and bring into reality the concept of the EDOS-in-a-Box (EBox).

- **EBox-S** configured in the “send” mode deployed at the GSIFs (replaces the DDCD).
- **EBox-R** configured in the “receive” mode deployed at the LZPF (replaces both the HRSP and PDP processors)
- **Monitor and Control System (M&CS)** provides a centralized and streamlined view of health & status of EDOS components



EDOS DATA-DRIVEN PHASE 2 Scheduled for November 2007



Fiber
1 Gbps Cu





EDOS DATA-DRIVEN PHASE 2

November 2007



Key design points guiding the current effort...

- EDOS operator screens standardized and accessed via a web browser
 - Web server provides status to remote users
- Operation intervention is only required on system anomalies
- New front end processing design:
 - Increases EDOS spacecraft capture rate to 500 Mbps, and
 - Allows flexible reconfiguration/upgrades via FPGA image file
- HRSP and the PDP hardware consolidation
- Ground Station hardware upgrade using the latest technology
- Traffic prioritization on the high rate lines between the GSIFs and the LZPF
- Archive data storage now based on disks (no longer on tapes)



EDOS DATA-DRIVEN - PHASE 2

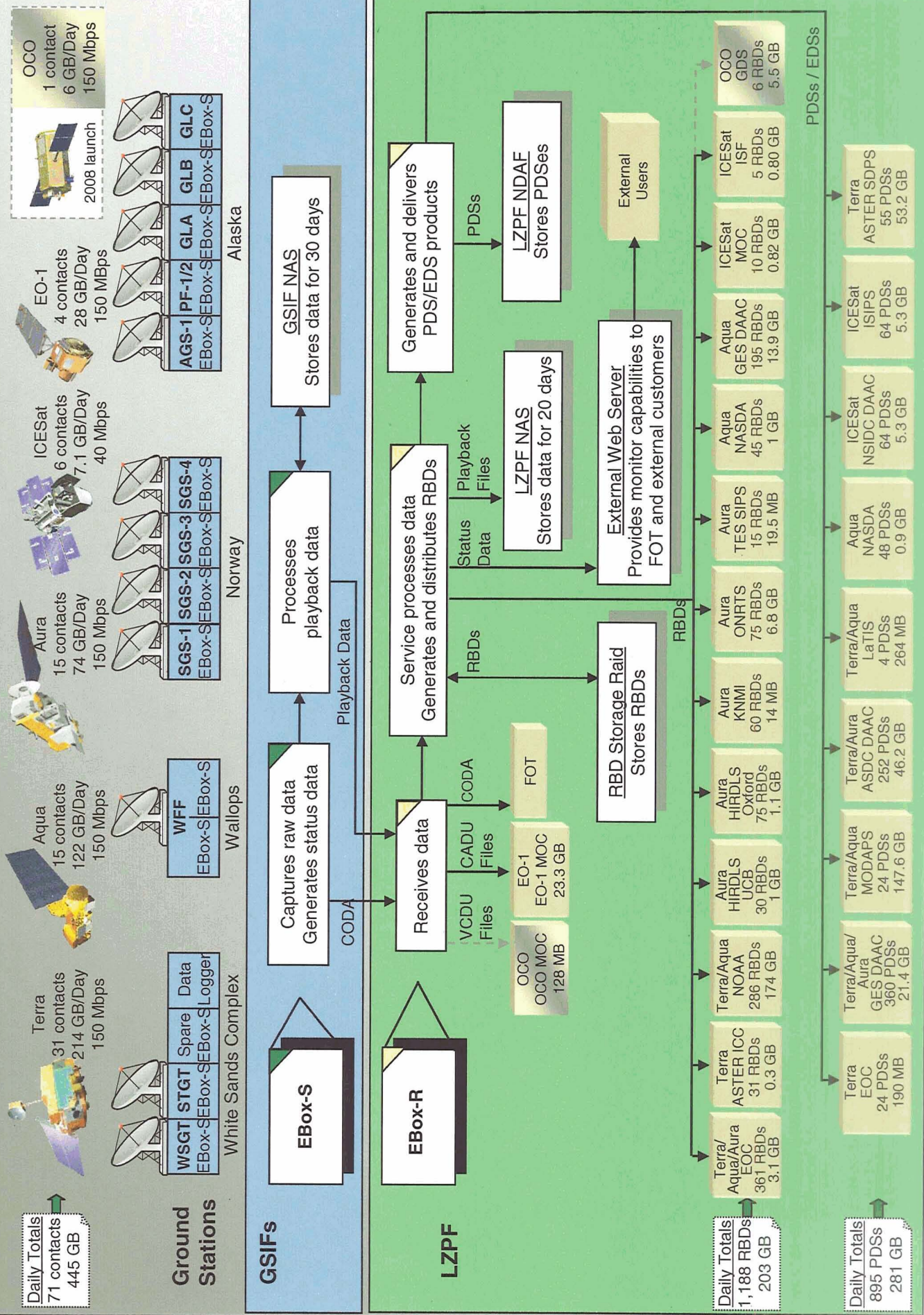
November 2007



Status to-date...

- The integration of the C5.1 components into a GSFC test system is currently ongoing
- The KSPT team is focused on delivering the EBox-S, the EBox-R and the M&CS (including the MEOS software and the middleware components).
- The EDOS developers concentrate their effort on the configuration and integration of the EBox-R
- Both teams are finalizing the GUI screens and functionality.
- Planned deployment: **Mid-November 2007 at the earliest.**

EDOS Data-Driven – Phase 2 (November 2007)





EDOS DATA-DRIVEN - PHASE 2

November 2007



Post Phase 2 Items...

- **Overlap**
 - EDOS does the service processing on a contact session basis. To recover packets at the end of each contact, EDOS needs to retain frames from one contact to the next.
- **Streaming real-time.**
 - Extract several virtual channels from the X-band downlink in real-time and stream to an end-destination



EDOS DATA-DRIVEN - PHASE 3

November 2008



Under consideration ...

- **Products Server**

- Push all products to a central server and let the users pull their own data. The data would remain available on the server for 10 days. This reduces the workload on the EBox-R servers.

- **More Robust Quality Assurance Tools**

- Automate “quality assurance” processes to detect and report on product anomalies using inference engines tools



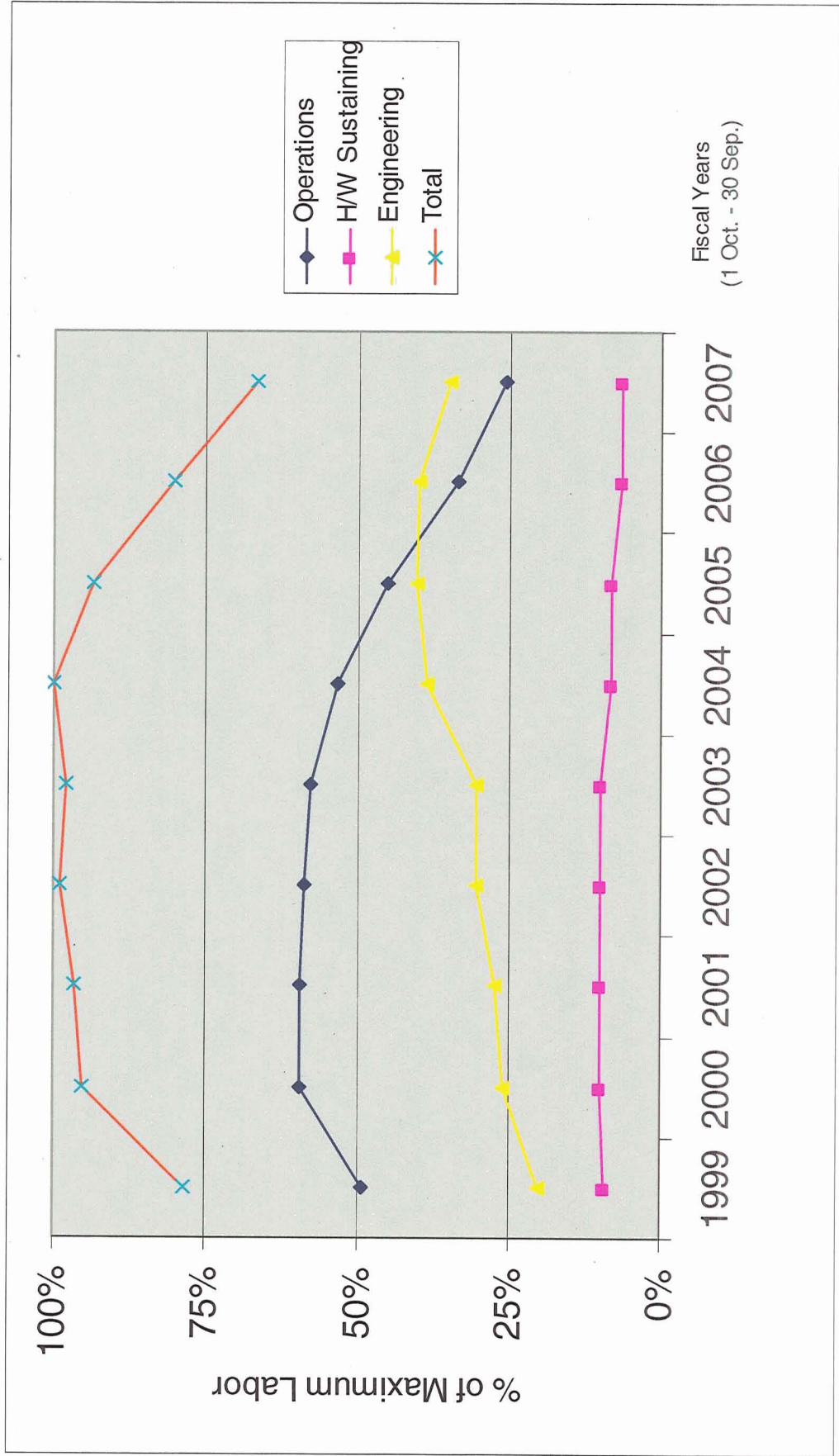
Summary



- The data-driven solution deployed under Phase 1 simplified operations in a major way. The methodology has been validated. Credit go to the KSPT and the EDOS development teams for resolving bugs on a timely basis
 - Significant reduction of workload on console operators
- Under Phase 2, all computer/ hosts processors will be replaced with a single platform, one O/S, and leading edge data ingest technology. Operations personnel will be able to focus on anomaly investigation.
 - Significant reduction of EDOS hardware and system maintenance costs
- Under Phase 3, EDOS products will be delivered to a central data server, providing much increased flexibility to users
 - Eliminates rework caused by data user facilities and network problems

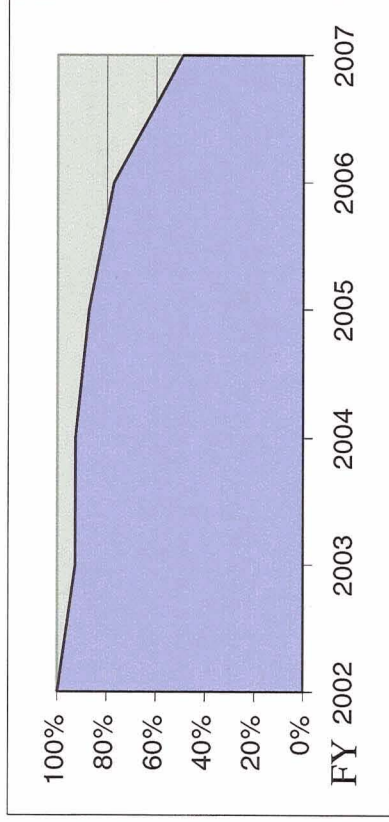


EDOS Staffing Trend To-Date





EDOS Budget Expenditures Trend



Factors affecting the expenditures:

- 2003 • Decline in system development costs
- 2004 • Operational efficiencies leading to reduction in operations positions
 - Reduction in management and administrative support as positions were reduced
- 2005 • Reduction in mission engineering and project troubleshooting positions as on-orbit missions stabilized into routine operations and there was limited new mission development work
- 2006 • Operational efficiencies as system stabilized and became more automated
 - NAS implementation eliminated maintenance costs of Ampex drives and eliminated tape handler positions
 - Savings at WSC with the data-logger LOR



Data-Driven Implementation Lessons Learned



1. Phase 1 was successful because of the close cooperation between two teams (KSPT and EDOS) able to bring their respective experience and skills to the solution.
2. The data-driven technique has stood up to the test of over 26,000 spacecraft contacts, identified correctly for each mission.
3. The risks associated with such major system re-engineering work, converting a schedule driven system to a data-driven system are best mitigated by :
 - Employing a test system and applying sufficient resources and testing time to uncover defects, and
 - Conducting parallel operations before the system is placed on line.
4. Never expect software to be error-free.

The EDOS systems have now reached a new high level of dependability, flexibility and autonomy. It is the only known automated end-to-end High Rate Multi-Mission Data-Driven System!



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